Introducing Multicultural Virtual Collaboration to Engineering Students taking a CAx Applications Course

Aaron G. Ball,[1] C. Greg Jensen,[1] Jon Mikkelsen,[2] Alan Steeves,[2] Marcelo Augusto L. Alves,[3] and Osornio Correa Cuitlahuac[4]

[1] Brigham Young University, Provo, UT, USA 84602. cjensen@byu.edu aaronball85@gmail.com
[2] University of British Columbia, Vancouver, BC, CANADA. mikk@mech.ubc.ca Alan@mech.ubc.ca
[3] University of Sao Paulo, Sao Paulo, SP, BRAZIL. malalves@usp.br
[4] Universidad Iberoamericana, Mexico City, DF, MEXICO. cuitlahuac.osornio@uia.mx

Abstract

In 2005 Friedman suggested that the world was becoming "flat", a reference not to world-altering geological changes, but rather to global-scale societal changes brought about by the convergence of several political and technological factors that are affecting the manner in which products are designed, analyzed, manufactured, and distributed. Ten years ago many corporations (i.e. General Motors, Boeing, General Electric, etc.) had plants, divisions, and employees scattered in many regions of the world; however, these regional divisions were in large part independently operated. It was rare at that time for a global corporation to even partner with a local firm in an emerging country to provide services, let alone allow them to be an equal design, analysis, or manufacturing partner on their latest global product. Such is not the case in 2010, and the effects of a world becoming "flattened" are likely to become even more pronounced in all engineering and manufacturing firms regardless of size. The challenge now confronting university engineering departments is to prepare their graduates for active participation and leadership in the burgeoning collaboration paradigm based on multicultural virtual design teams.

This paper discusses the transformation of a project based Brigham Young University (BYU) Computer-Aided Engineering applications course (ME 471) into a Siemens Teamcenter enabled global engineering applications course. Students from Canada, Mexico, Brazil, and the United States were organized into multicultural virtual teams and participated in designing, analyzing, and prototyping three competing auto body styles based on a common vehicle platform. A discussion of the technologies used, the modification and addition of content to the original lectures and labs, and the lessons that have been learned are presented. Intercultural and virtual teaming competencies are proposed as a result of our research and form the basis for an improved version of the ME 471 class that will be offered beginning September 2010. An Institutional Participation Packet (ME 471 course information and institutional agreements) is available, and an invitation for participation in September 2010 is extended to PACE institutions.

Introduction

The 'flattening of the world', using Thomas Friedman's phraseology, is an ongoing process that was initiated by the convergence of political and technological factors. It is a process that continues to reshape and redefine the world as we know it [1]. Cultures, societies, and economies alike are becoming more integrated through this process of globalization [2-6]. Recognizing that this trend is likely to not only continue, but also become more pervasive in the future [2, 7], corporations throughout the world are increasingly using intercultural teams to meet the rising challenges and opportunities of operating on a global scale [4, 5, 7]. Similarly on the academic front, scholars have followed these trends, and have recognized the need to globalize the traditional university educational curriculum [2, 8-10].

ME 471, a project based Computer-Aided Engineering applications course taught at Brigham Young University (BYU) is being redesigned to help students develop elements of intercultural competence. This represents one attempt to prepare graduates for active participation and leadership in the burgeoning collaboration paradigm based on multicultural virtual design teams. As a first step, ME 471 taught in Fall 2009 was transformed into a Siemens Teamcenter enabled global engineering applications course wherein students from Canada, Mexico, Brazil, and the United States participated in multicultural virtual design teams to design and analyze an automobile vehicle concept. This paper details the transformation of the traditional ME 471 course into a globalized team-based CAx course, discusses lessons that were learned from the Fall 2009 course offering, and describes the redesigned ME 471 course scheduled to be taught in Fall 2010.

Background/Literature Review

The ability to work in a global environment has been described using many terms including: intercultural competence, cross-cultural competence, global competence, global citizenship, and global awareness [3, 6, 9, 11-12]. In addition to these terms, the *definitions* for these terms have also varied considerably [6, 9, 11]. As noted by Parkinson et. al., it is necessary to plainly define the cross-cultural ability in order for it to be taught, developed, and assessed [6]. For the purposes of this paper, we will use the term 'intercultural competence' to refer to the ability to work in a global context, and define it as: the set of knowledge, skills, and attitudes necessary to facilitate the successful interaction and communication of an individual with other persons of a different culture.

Various elements of intercultural competency have been proposed in the literature. Several of these elements that are non-specific to an engineering curriculum include: speaking a foreign language, cross-cultural awareness, the ability to participate in global political and social events, an understanding of the world and it's systems, a general knowledge of world history, sociology, and geography, an understanding of globalization and sustainability concepts [2]; understanding others' worldviews, cultural self-awareness and the capacity for self-assessment, adaptability and adjustment to a new cultural environment, skills to listen and observe, a general openness toward intercultural learning and to people from other cultures, and an ability to adapt to varying intercultural communication and learning styles [11].

Additional engineering specific elements of intercultural competency have been proposed as well. Some of these include: understanding cultural differences related to product design, manufacture and use; understanding the implications of cultural differences on how engineering tasks might be approached; practicing engineering in a global context [6].

Identifying the competencies required to work in a global context runs tandem to identifying the challenges that students face in intercultural interactions. Through reviewing the literature, a set of intercultural competencies of both a general and engineering specific nature have been identified. Ongoing research at BYU is focused on establishing and validating this set of intercultural competencies and intercultural learning outcomes based on those competencies for a mechanical engineering curriculum. It is anticipated that the results of this research will aid the ME 471 course and other institutions as they seek to develop and assess international and intercultural student engineering programs.

Numerous programs are currently being operated across the country and throughout the world to promote international and intercultural education among engineering students [8, 13-14]. These programs are offered in a variety of types. Each program type has advantages and disadvantages over other programs [14]. Table 1 lists a representative sample of these types of programs and an example set of universities that offer that program type. Although numerous programs are offered, it is estimated that only a small fraction—3% according to the Institute for International Education [13] and 7.5% according to ASEE graduation data [14]—of U.S. undergraduate engineering students are participating in an international experience.

Table 1: Sample of Program Types and Universities Offering Those Types of Programs*

Program Type	**Universities Offering Program Type**
Double Major or Dual Degree Programs	Pennsylvania State University, Iowa State University, and University of Rhode Island
Minors or Certificates	Georgia Tech, Iowa State University, Purdue University, University of Illinois, University of Michigan, University of Pittsburgh
International Internships, International Co-Op	Georgia Tech, MIT, University of Rhode Island, University of Cincinnati
International Projects	Worcester Polytechnic Institute
Study Abroad and Academic Exchange	University of Minnesota, Rensselaer, Global E3
Collaborative Research Projects and Global Teaming with Partners Abroad	Purdue University, Harvey Mudd
Service Learning Projects Abroad	University of South Florida, Worcester Polytechnic University, University of Dayton, Duke University
Graduate-Level International Programs, including research experiences abroad, research collaborations with colleagues abroad, dual and joint degree programs with partner universities abroad	University of Rhode Island Dual Degree Masters and Doctoral Programs, NSF PIRE and IREE projects

* Table adapted from list in [13]

International programs of the 'Collaborative Research Projects and Global Teaming with Partners Abroad' category type—such as the ME 471 course—while not the sole solution to improving student participation in international programs, are scalable programs that can provide students with international and intercultural experiences. PACE global projects are excellent examples of programs of this type [15-18]. Collaborative global teaming projects are less costly for the college, and generally are less costly for students as well. They still, however, require significant faculty oversight and involvement. Also, more students can be accommodated through this method than through many of the other program types. Research currently being conducted at BYU that involves the ME 471 course is focused on determining what elements of intercultural competence can be provided in collaborative global teaming program types in comparison to other program types, such as service learning projects, study abroad programs, and international internships. It is thought that each program type will serve as a unique and complementary part in a college's portfolio of international programs.

Traditional ME 471

ME 471 is an advanced course in computer aided engineering applications that has been taught at BYU for 30 years. The emphasis of the course has always been to instruct the student on how to solve real world problems using available CAx tools; however, the specific tools and procedures that are taught are updated to be current with available, state of the art CAx technologies. In Fall 2008, principles taught related to concepts of topology optimization, surface and advanced solid modeling techniques, parametric modeling approaches, assembly animation and kinematic analysis, manufacturing model preparation, and team based engineering.

The structure of the course is designed to provide the students with ample opportunity to learn CAx tools and concepts through instruction and practice. The course consists of class and lab components: the classroom component facilitates instruction of the theoretical and mathematical basis of CAx tools, whereas lab activities emphasize learning advanced practical CAx skills. Student assessment is based on homework assignments, quizzes, lab assignments, design reviews and final project presentations, and midterm and final exams.

Students in ME 471 are organized into teams to work on a 16 week design project. The design projects require significant student effort, necessitating complete team member participation. Design projects are also chosen such that they require the students to apply advanced CAx principles that have been taught in the course. To best facilitate student application of these skills on the design projects, topics in ME 471 are sequenced to be taught during the semester when the teams will most benefit from the instruction.

Students are provided with multiple sources of learning materials to help them to master ME 471 course content. An English text that emphasizes CAx theory and mathematics is required from which reading assignments are given and homework problems are assigned. Laboratory materials are provided to assist the students in learning advanced practical CAx skills. The course professor is available to provide assistance to the students outside of class, and a teaching assistant (usually a graduate student) is also available to meet with students to mentor them on course topics.

Fall 2009 Global ME 471

To begin to evaluate the feasibility and effectiveness of using virtual collaboration in a classroom environment as a method to provide students with opportunities to learn elements of intercultural competence, the BYU ME 471 class was transformed and offered as a pilot international advanced CAx course. Other universities that participated in the pilot course included: University of British Columbia (Canada), University of Toronto (Canada), Universidad Iberoamericana (Mexico), ITESM-Toluca (Mexico), and the University of Sao Paulo (Brazil). Portions of the course objectives, structure, content, and logistics were modified to accommodate the new international emphasis. These modifications made at BYU as well as perspectives from the other partner universities regarding the setup, operation, and coordination of the course are detailed below.

Several course outcomes were added to the course to reflect its intercultural emphasis. These new intercultural outcomes are listed in Table 2. In a previous study, Parkinson, et. al. proposed thirteen elements that together comprise intercultural competence [6]. From this list of elements of intercultural competence, three elements were identified that could be integrated into the ME 471 course. This decision was reached by considering the ease with which the elements could be incorporated in the course and their natural fit related to the traditional emphases of the course.

Table 2: Added ME 471 Course Outcomes

Experience working in or directing a team of ethnic and cultural diversity.
Understand cultural influences on product design, manufacture and use.
Understand how cultural differences affect how engineering tasks are performed.

The structure of the course remained largely unchanged. Classroom instruction, laboratory training and exercises, as well as reading and homework assignments, and examinations all remained integral parts of the course. The major change in the structure of the course was the integration of international teams. Table 3 shows the number of students that participated from each school.

Table 3: Student Distribution By University

	BYU	UBC	Toronto	UIA	Toluca	USP
Number of Students	21	14	2	4	4	5

All of the students in the course were asked to respond to a short questionnaire wherein they provided information about their previous engineering experience, CAx and team skills, foreign language(s) fluency, and personal interests. Using this information, the course professors strategically organized the students into teams according to language ability, engineering experience, and geographical location.

Four international teams were created. Table 4 shows the distribution of students in each team by participating university.

Table 4: Student Team Composition By University

Team	BYU	UBC	Toronto	UIA	Toluca	USP
Team 1	5	4	-	-	4	-
Team 2	6	4	-	4	-	-
Team 3	5	2	2	-	-	3
Team 4	5	4	-	-	-	2

The processes used to grade student work varied by assignment type, necessitated by the ways in which the participating universities offered the course (i.e. not all of the students participating in the course were receiving university engineering credit for the course). Individual homework assignments were submitted to local faculty members. Team project presentations, reports, and other deliverables as well as lab assignments were graded by the BYU professor or TA. Although assessment and student performance was discussed among all of the professors, ultimately, the local university professors had responsibility for determining grades for their own students.

Course content and learning materials were added, modified, or in some cases, removed to meet the altered set of course learning outcomes and objectives. Two new lectures focused on intercultural topics were developed. The first new lecture introduced the idea of and the need for global competence, also discussing the need to avoid ethnocentrism. The second lecture focused on principles of intercultural communication. Material for these lectures was based on topics published throughout the literature. To make room for the new lectures, several lectures that focused on IGES/STEP and data exchange were merged. In addition, some of the manufacturing content was dropped.

Several new technologies were integrated into the course to support virtual student team interactions. Siemens Teamcenter Community (TcC) was selected and used to accommodate each team's work-group needs (i.e. calendaring, task assignments, asynchronous discussions, application sharing). TcC was also used as the teams' primary secure file hosting and file sharing utility. It also hosted course presentations, assignments, and other materials posted by the course professors. TcC was selected because it was readily available to the participants and had been successfully used in past PACE projects. Other free web-based tools to supplement team processes were used as well, including Skype and the online Google Docs Suite.

A new laboratory exercise was also developed to introduce technologies that students would use to collaborate with their distributed teammates. Instruction was provided on how to use TcC, Skype, and Google Docs. In addition, instruction on how to interact with teammates in a distributed team environment was provided. The existing team-building lab was augmented to accommodate the newly developed material that would prepare the students to work in a distributed team environment.

Numerous other logistical challenges were addressed to ensure that the course operated smoothly. First, collaborative technologies were integrated into the course to support three primary logistical areas: faculty correlation, class lectures and lab instruction, and team activities. Video conferencing equipment was utilized as the primary technology to support faculty, class, and lab communication. This decision was made based upon the availability of such equipment at each of the participating universities, and the high level of audio and video quality provided by these systems. Table 5 lists the video conferencing systems that were used at each university.

Table 5: Video conferencing hardware used by participating university

University	Equipment Used
BYU	Tandberg 880MXP Endpoint Tandberg Edge 95MXP Endpoint Tandberg Codian MCU conferencing 'Bridge'
UBC	Tandberg 990MXP Endpoint
Toronto	Tandberg Edge 95MXP Endpoint
UIA	Tandberg 880MXP Endpoint
Toluca	Polycom Endpoint
USP	Polycom V500 Endpoint

Course lectures and lab instruction were provided by professors and teaching assistants at BYU and made available via video conferencing technology to the other participating universities. BYU used two different video conferencing endpoint units to facilitate communication activities throughout the course. The first system was in a small conference room in the PACE ParaCAD Lab, and served as the primary collaboration area (at BYU) for weekly faculty meetings. Because the ME 471 lecture and laboratory activities at BYU were not available in a common classroom that supported video conferencing, a second mobile video conferencing unit was designed that could be used in any of the classrooms in which the ME 471 course was scheduled. This mobile unit supported the conferencing needs for both classroom and laboratory instruction.

In addition to endpoint video conferencing units, a multimedia conferencing bridge ('bridge') accommodated videoconferencing between the more than three partner universities. The bridge (pre-existing video-conferencing hardware at BYU) supports up to high-definition video conferencing capability for up to 40 different conference participants and was an invaluable, readily available hardware component that was necessary to support multi-university participation.

Student team members at BYU were provided (through a checkout system) with headsets and web cameras to support just-in-time team collaboration activities. Teams at BYU had the flexibility to schedule the video conferencing room for team use as well as the ability to collaborate via Skype.

Additional logistical challenges included differences in university course calendaring and time-zones. Recognizing that semester/term beginning and ending dates, holidays, and other breaks did not align, plans were made to ensure that lectures, lecture materials, laboratory instruction, and assignments were available both through synchronous and asynchronous communication methods. Lectures and labs were recorded and posted on YouTube so that they could be reviewed at any time. This was beneficial for students that were unable to connect synchronously for class. Planning and coordinating schedules in advance helped to mitigate, but did not eliminate all problems incurred because of calendaring and time differences.

Reasons for participation in ME 471 varied among institutions. BYU was interested in providing a scalable, low cost opportunity for local students to interact with students from another country in an engineering design team context. UBC does not teach an advanced CAx applications course, so the course topic was an incentive to participate. When coupled with an opportunity to learn collaborative tools and practice those skills, it was recognized as an incredible experience. Faculty at USP were excited to participate because one of the school's current objectives is to increase the internationalization of its undergraduate courses. Also, the students were motivated by the possibility of working with fellow students abroad, and had worked with BYU on previous PACE Global projects. As a final example, UIA elected to participate because of the ambitious ME 471 syllabus and the opportunity provided for students to use internet and videoconferencing communication tools.

Students at each university were recruited in different ways. At BYU, student interest in the ME 471 class has always been considerable and offering the international version of the course did not adversely affect student interest. All interested students were invited to participate. At UIA, students were selected from the four credit "Computational Product Simulation-IN041" course. Twenty students typically participate in this course. The four best students in this course were selected to participate in ME 471. The students were in the top ten "best students of their generation 2007-2010". Additionally, they have excellent written and oral proficiency in English. Students at USP were recruited from the group that was working on the PACE Global project and were already closer to Dr. Alves' laboratory. Students attending UBC's MECH 328 (a third year design project course) were provided with the option of applying to take the Global ME 471 class and use its design project to fulfill the requirement for their MECH 328 project. Students applied via an e-mailed letter explaining why they would like to participate and why they should be selected. The selections were based on their letters and their grades.

Lessons Learned

Although each of the partner universities had previous international student program experience (i.e. PACE activities, or other international courses), many lessons were learned from the Fall 2009 course. The lessons learned presented in this paper are qualitative in nature, and are the result of one of the following feedback methods: student surveys, student and faculty interviews, and faculty observations.

Course Logistics

The logistical aspects of integrating a course among multiple universities internationally present significant challenges. Advanced preparation is essential in successfully operating a course of this nature. Planning for differences in calendaring (including holidays, semester schedules, etc.) and time zone differences is critical. The adjustment away from and on to daylight savings time was a particular challenge in the course. For example, at the beginning of the semester USP was 3 hours ahead of BYU. As the USA ended the daylight savings period, this difference went to 4 hours. Later in the same semester when Brazil moved into its daylight savings period, the difference increased to a total of 5 hours. In one case, one of the universities had a staff member attend the lab sessions so that he could re-teach the lab to his local students who were unable to attend the lab concurrently. Although scheduling conflicts with students, faculty, and video conferencing facilities were mostly avoided, additional planning and advance student notification would alleviate problems that were encountered.

The importance of providing instructional materials to all students prior to class was another lesson that was learned. Internet bandwidth varied among universities and throughout the duration of course (some universities were affected more than others) and had a direct effect upon the quality of the presentations, lectures, and labs. Providing electronic copies of course materials in advance ensured that all students could clearly see and better understand course material.

Having redundant communication technologies in place is also important. It was learned that if one of the universities had difficulty connecting to the video conference, there was little that could be done to correct the problem during class. Establishing videoconferencing connections ten to fifteen minutes prior to each class period would decrease potential disruptions during class. Also, conferencing disruptions would be mitigated by having a faculty or staff member at each institution online via Skype, which would function as a standby backup communication and troubleshooting medium.

Faculty Involvement

A high level of faculty commitment is required for a successful international course experience. Frequent faculty correlation regarding lectures, student comprehension and assessment, and calendaring was necessary. Faculty at UBC noted that much more faculty time was required than was originally expected. Each university provided varying mentoring resources for their local students as well. Although a teaching assistant at BYU was available to help students at each of the universities via Skype, few students took advantage of this opportunity. It was learned that it is important that faculty are provided with information to help them best understand the commitment involved, and that students are provided with local as well as remote mentoring resources.

Course Improvements

Course credit for the students participating in the ME 471 course needs to be more streamlined. Only some of the partner universities provided their students with some type of equivalent mechanical engineering course credit for participating in ME 471. For example, USP enrolled students in PME2596 – Special Topics in Mechanical Engineering. In contrast, UBC provided ME 471 as an option to students in MECH 328, a third year design project course. The lack of uniformity in offering engineering credit to students participating in the course had deleterious effects on team operations. Whereas some students were overloaded by attempting to fulfill the requirements of the ME 471 course as part of another course in which they were enrolled, other students participated in more of an extracurricular way. Ensuring a more uniform credit offering would help to provide equal motivation for students to participate in the team projects.

Students recommended several changes to improve the course offering. First, students felt that there needed to be a better delineation of the responsibilities and expectations required of them and their teams in labs, assignments and projects. A higher level of uncertainty and ambiguity can be felt by students participating in a distributed team environment over a co-located team. Providing additional instructional materials and teaming requirements may help students to better operate in this environment. Also, the sequencing of some of the course lectures needed to be altered to provide students with the skills they needed for their design projects in a more timely manner.

Ensuring student involvement and interaction proved to be challenging. It was noted that at times it was hard to hear questions asked by BYU students. Also, students suggested that it was more difficult to ask questions as a remote student to the lecturing professor at a different university. Some students at universities participating through video conferencing did not feel that they understood completely what was being taught in the lectures. From this, it was learned that concerted effort must be taken to create an environment and processes such that students participating through video conferencing are involved in lectures and that their understanding of the material can be better understood.

Student Teams

Decreasing student team size was a suggestion made by multiple students and an observed need made by faculty members as well. It was quite difficult for the teams to schedule their meetings such that everyone could synchronously participate. This was not only true because of the size of the teams, but also because several teams were composed of students from more than two universities. Coordinating student schedules in addition to time zone differences proved to be very challenging. Despite the challenges, each international student team performed well and produced high quality project deliverables at the end of the course. Figures 1 through 6 provide examples of some of the modeling and analysis work completed by the distributed teams.

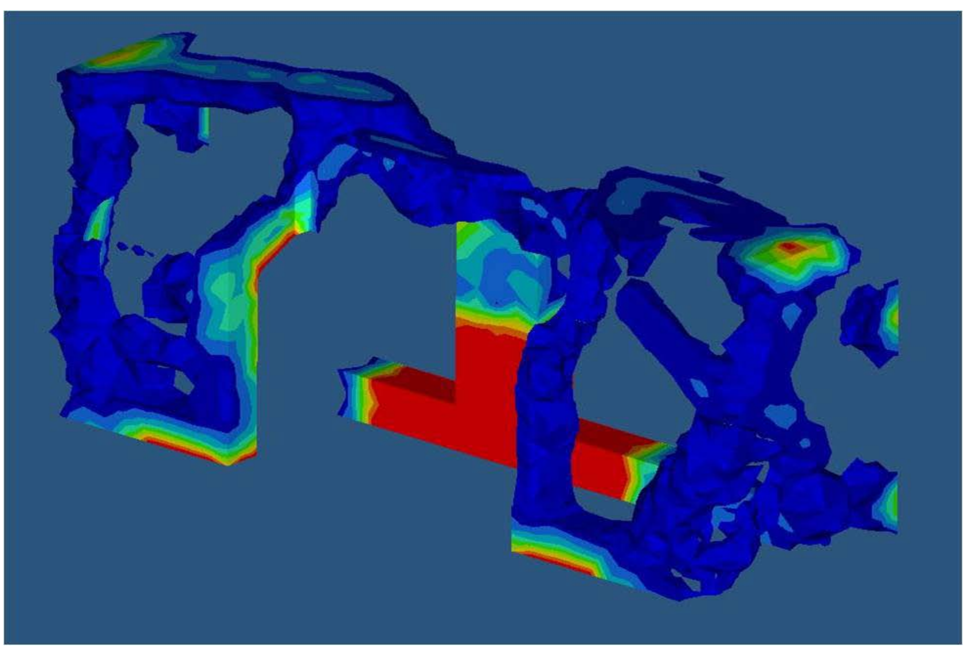

Figure 1: Topology optimization result for automobile structural supports.

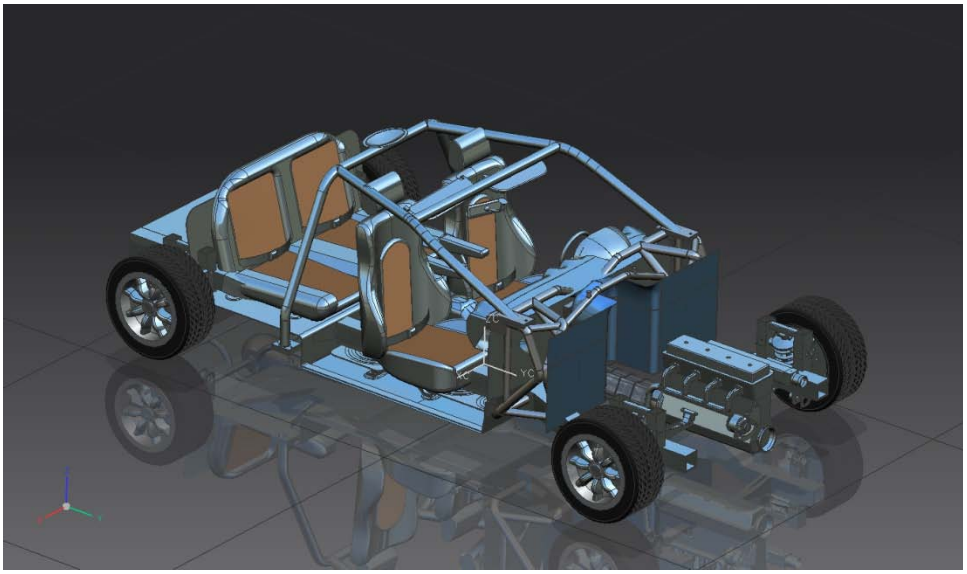

Figure 2: Assembly model of vehicle powertrain, interior, and chassis.

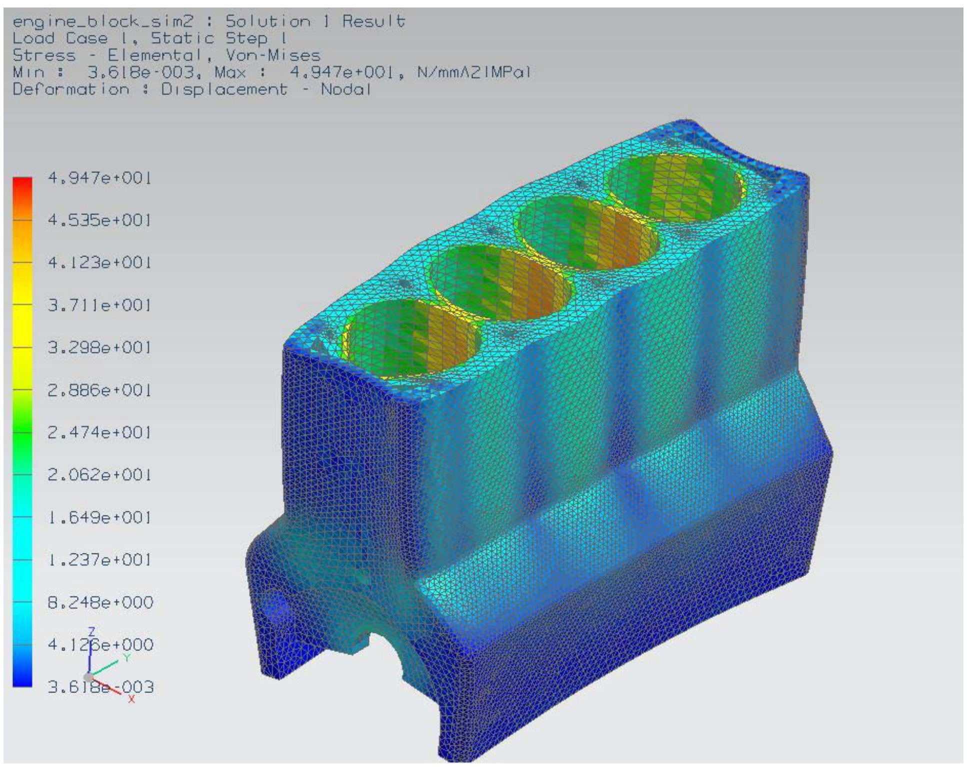

Figure 3: Finite element analysis of engine cylinder block.

Figure 4: Rendering of vehicle interior.

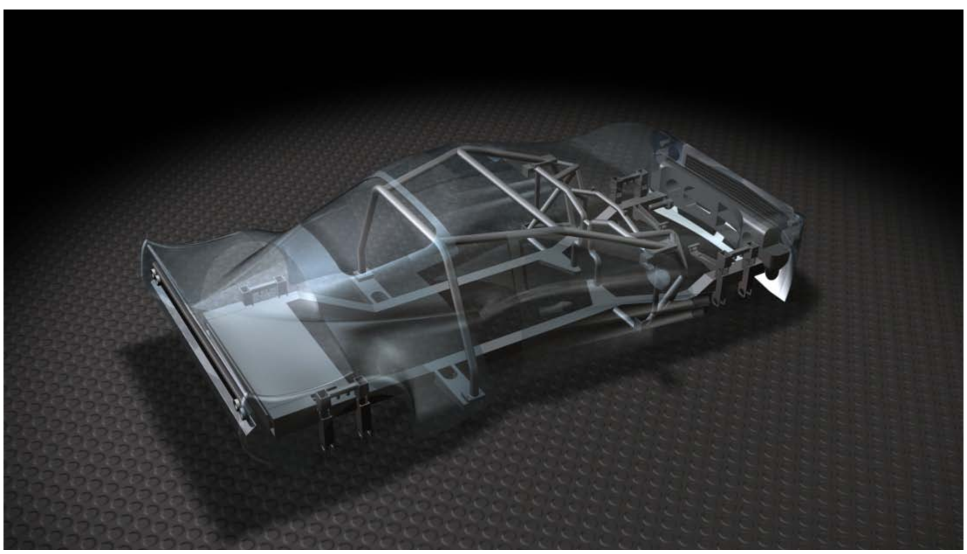

Figure 5: Rendering of vehicle frame with transparent body.

Figure 6: Rendering of automobile assembly.

Finally, providing opportunities for students to become better acquainted with teammates was another important lesson learned. A large majority of students responded in a survey that they wanted more interaction with the students at the other universities. The students noted that it was challenging to get to know their colleagues in the virtual environment. The need for student incentives to associate with and learn about their distributed team members should not be underestimated.

Fall 2010 Global ME 471

The Fall 2010 offering of ME 471 will implement several changes to improve the globalized course while maintaining the emphasis on learning advanced CAx tools and concepts. The course outcomes and objectives will remain largely the same. However, several changes in the course structure, content and learning materials, and logistics will be implemented to improve the faculty and student experience. The changes mentioned here are not extensive, but rather representative of the changes that are being made to improve the distributed teaming experience of the students.

Several changes to the structure of the course will be made to improve student teaming experiences. First, a new paradigm is being used to structure the student teams. Teams will be composed of six students in total, reducing the team size from the Fall 2009 course by about 50%. Three students from BYU will be paired with three students from another university. This new paradigm will reduce the number of time zone, calendaring, and other scheduling difficulties that the students will experience when working in their teams.

Siemens Teamcenter Engineering (TcE) software, a product lifecycle management (PLM) database, will also be utilized. TcE will offer several advantages to the distributed student teams. Improved support for model versioning, handling of part and assembly files, and check-in and check-out features are several of the benefits of using this system. TcE will handle project data management and will be used in conjunction with Teamcenter Community (TcC) and collaborative tools such as Skype, which will support team collaboration. The labs introducing the collaborative tools to the students will be augmented to also introduce TcE.

Additions and modifications to course content will be made to assist the students and faculty in working in a distributed teaming environment. Learning materials outlining good virtual teaming practices and student expectations will be created. Documentation indicating the estimated faculty and student time and communication commitments necessary to facilitate successful student distributed team projects will also be created. Also, course materials will be provided to students prior to class lectures and labs to facilitate improved student understanding of course content.

Course logistics will also be improved in the Fall 2010 ME 471 course offering. Increased effort will be made to ensure that calendaring, time zone, and Daylight Savings Time changes are better understood and prepared for such that student and course collaborations will be more seamless. Tests will be conducted with each participating university to detect and resolve connectivity issues prior to the beginning of the course. In addition, communication protocols will be developed with backup plans in place to prepare for unexpected technology problems. Also, efforts will be made to ensure that students participating in the course receive course credit that is as inter-institutionally similar as possible. This will promote equal student motivation and accountability in course participation and team interaction.

Conclusion

ME 471 at BYU has traditionally been a course that has emphasized the instruction of advanced CAx tools and concepts. In Fall 2009, ME 471 was revamped to incorporate a global emphasis in which students at partner universities throughout the world attended distance learning lectures and labs, and were organized into distributed teams working on a course-length (16 week) project. Feedback from students and faculty that participated in this experience was overwhelmingly positive. However, as with any pilot program, many lessons were learned from this experience. The Fall 2010 course offering of ME 471 will incorporate many changes resulting from feedback received from the students and faculty that participated in 2009.

We invite any institutions interested in participating in the Fall 2010 ME 471 International Advanced CAx course to contact Dr. Greg Jensen (cjensen@byu.edu) or Aaron Ball (aaronball85@gmail.com) to express their interest. Institutions that participated in the Fall 2009 ME 471 course as well as several additional universities have already expressed interest in participating in the course during Fall 2010. Because advanced institutional planning and preparations are necessary to ensure proper course operation, we encourage timely response from those interested in participating in Fall 2010 or beyond. Information regarding the logistical requirements for participation, student and faculty expectations, course topics covered, or other inquiries are available upon request.

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